A proposed simulation optimization model framework for emergency department problems in public hospital

Ireen Munira Ibrahim, Choong-Yeun Liong, Sakhinah Abu Bakar, Norazura Ahmad, and Ahmad Farid Najmuddin

Citation: AIP Conference Proceedings **1691**, 030011 (2015); doi: 10.1063/1.4937030

View online: http://dx.doi.org/10.1063/1.4937030

View Table of Contents: http://scitation.aip.org/content/aip/proceeding/aipcp/1691?ver=pdfcov

Published by the AIP Publishing

A Proposed Simulation Optimization Model Framework for Emergency Department Problems in Public Hospital

Ireen Munira Ibrahim[1,a)], Choong-Yeun Liong[2,b)], Sakhinah Abu Bakar[2,c)], Norazura Ahmad[3,d)] and Ahmad Farid Najmuddin[1,e)]

[1]*Faculty of Computer and Mathematical Sciences*
Universiti Teknologi MARA (Perak)
35400 Tapah, Perak, Malaysia
[2]*School of Mathematical Sciences*
Faculty of Science and Technology
Universiti Kebangsaan Malaysia
43600 UKM Bangi, Selangor, Malaysia
[3]*School of Quantitative Sciences*
College of Arts and Sciences
Universiti Utara Malaysia
06010, Sintok, Kedah, Malaysia

[a)]ireen607@perak.uitm.edu.my
[b)]lg@ukm.edu.my
[c)]sakhinah@ukm.edu.my
[d)]norazura@uum.edu.my
[e)]ahmad824@perak.uitm.edu.my

Abstract. The Emergency Department (ED) is a very complex system with limited resources to support increase in demand. ED services are considered as good quality if they can meet the patient's expectation. Long waiting times and length of stay is always the main problem faced by the management. The management of ED should give greater emphasis on their capacity of resources in order to increase the quality of services, which conforms to patient satisfaction. This paper is a review of work in progress of a study being conducted in a government hospital in Selangor, Malaysia. This paper proposed a simulation optimization model framework which is used to study ED operations and problems as well as to find an optimal solution to the problems. The integration of simulation and optimization is hoped can assist management in decision making process regarding their resource capacity planning in order to improve current and future ED operations.

INTRODUCTION

Everyone requires good services and what is considered as a good service can be interpreted in many different ways. In healthcare industry, the most concerned issue is the quality of care and the efficiency of the services to the patients. The patient always seeks for quick services. They always hope that when they arrive at the healthcare center, they will be diagnosed as soon as possible without having to face a long queue. Patients not only look at the result of the treatment provided, but they also consider the process while receiving the treatment.

Emergency department (ED) operates 24 hours to serve patients of any kind of injuries and diseases. Waiting times are too long and patients have to spend too much time during the process of obtaining the required services. This may cause dissatisfaction among patients and staffs (having to work for long hours). Patient congestion and

Innovation and Analytics Conference and Exhibition (IACE 2015)
AIP Conf. Proc. 1691, 030011-1–030011-8; doi: 10.1063/1.4937030

long waiting time (LWT) are among the common problems faced by worldwide ED. Several studies highlighted that these problems are related to limited resources, which require proper planning and allocation [1-2]. According to Baesler et al. [3], the smooth running processes in the ED are closely related to capacity planning.

Efforts to improve the efficiency of an operation would involve additional resources (for example; hiring more staff or adding new equipment) and this will increase the cost of operations. The efficiency of the operations should be improved without increasing costs. This can be done by examining the processes in details, allocating the resources more effectively and using technological solutions. These methods can decrease the LWT as well as length of stay (LOS), which truly is the biggest problem to the emergency departments.

Even though it is pretty possible to come out with new recommendations to solve the problems, the issues are still lie in finding the best solution which can validate the effects on the whole operations. Traditionally, the decisions (such as staff scheduling, current or future resources and capacity planning, hiring new employees or purchasing new equipment) are mainly based on the experience of managers and staff where those decisions might not consider other factors that affecting the system of ED. This decision is quite risky and costly because the hospital environment is very complicated and complex which contains many constraints. To implement such decisions directly to the ED during operations is quite impossible because it might create other problems or congestions to the system. This is not the best solution to resolve the problems. Therefore, the appropriate and effective tools should be used to improve the operations as well as optimizing the performance. This tool should be able to represent the real environment of ED which then can be used to aids the managers of ED in planning their operations and strategies to enhance the efficiency of ED services.

In order to help the ED management in decision making process and also understanding the ED operations itself, this study propose a simulation optimization model to represent the operation of ED where this model helps in identifying bottlenecks and seeking the optimal solution to improve performance of the ED. This paper is organized as follows; Section 2 explains the motivation of the study, Section 3 describes related literature review. The proposed methodology for the problem is discussed in Section 4. The conclusions and future work are discussed in Section 5.

MOTIVATION OF THE STUDY

Generally, in Malaysian government hospital, ED's patients are generally classified into three triage categories based on Emergency Medicine and Trauma Service system; green, yellow and red. Patient with non-critical cases (walk-in and stable) is assigned to green zone. Patient with semi-critical cases (stable but unable to walk) is assigned to yellow zone and patient with critical cases (requiring urgent treatment) is assigned to red zone. Patients arrived at ED either by walk-in or ambulance mode. Those patients need to be attended by doctors within target time as stated by the Ministry of Health (MOH) in 2009 [4]. Those target times are shown in Table 1.

TABLE 1. MOH's New Target Time

Medical Triage Card	Time to be attended	
	Prior	New
Red	Immediately	Immediately
Yellow	30 minutes	15 minutes
Green	2 hours	90 minutes

The arrival of patient are unscheduled and every single patient must be attended as required. There is no such option as not to treat an arriving patient at ED. Patient tends to visit public ED because they want to be served as soon as possible compared to public clinic where they have to wait in queue. This factor might contribute to the increase of demand in ED. Besides, the increased in level of population will also increase the demand for health services [5].

According to Department of Statistic Malaysia, number of population for the state of Selangor increased from 5.6 million to 5.87 million in 2011 to 2014 and this will continue to increase in the coming years. There are only 11 hospitals in Selangor to facilitate the population [6] and the doctor-patient ratio in Selangor is recorded as 1: 781 while the nurse-patient ratio is 1: 490 [7]. This situation give pressures to ED management as they need to operate within limited resources (nurses, doctors, beds etc.) to treat their patients in short time.

The shortage of resources will contribute to LWT and LOS in ED as patients have to wait for their services until the required resources are available (for example, waiting for beds). This will leads to overcrowding and dissatisfaction among patients and staffs. To simply overcome this problem, ED management can provide more resources by hiring more staffs or increase number of bed but the question is, does adding more resources will improve the ED's operations? Does adding more resources will reduce patient's LWT and LOS? Therefore, studying and analyzing the patient flow through ED is extremely important as it can helps the ED management in decision process. This can be done by developing a model that can represent the real environment of ED which then can be used to examine and to understand resource capacity which can assist the management to make the right decision in order to improve the services as well as minimize the LWT and LOS.

This study aims to develop a simulation optimization model to determine the best allocation of resources in ED. The Discrete Event Simulation (DES) approach is used for modeling the ED operations. This is to aid the management's understanding of the patient flow, evaluating the current efficiency and identifying the bottlenecks in the system. The alternatives changes can be tested using this simulation model in order to evaluate the effect of those changes to the system performance without affecting the real system. Meanwhile, the optimization method is used to find the optimal solution to the problems identified in simulation model.

RELATED LITERATURE REVIEW

Hospital, especially the management, faced a big challenge in maintaining the quality of the services provided to the patient. Patient flow concept reflects the movement of patients through processes in a sequence as part of their pathways of care. It is considered to be the point to understand the key components pertinent to hospital performance, which includes queues, redundancies, capacity and demand [8]. According to Cote [9] in the article entitled "Understanding Patient Flow", understanding the flow of patients is also necessary to support the operation of the facility. Meanwhile Theory of Constraints agreed that solving bottlenecks problems is the most effective and efficient method to improve the patient flow in an organization [10]. Elbeyli and Krishnan [11] studied patient flows in a large hospital. The main goal was to locate the bottlenecks and study the effects of bed availability on waiting times. They suggested taking a closer look into emergency patient pathways and throughput in order to gain better understanding of the system, and also the problems involved in the process.

Feili [12] stated that patient overcrowding occurs in ED across the nation, where the decreased in the number of ED will increase the number of patients. Several studies have been carried out by previous researchers in finding the solutions to the problems faced by emergency department's management [13]. The objectives of most research are to reduce waiting time, to minimize length of stay, to maximize patient throughput, and also to optimize the resources allocations [14]. Jun et al. [15] stated that simulation model have been used in modeling outpatient department to model patient flow and queuing problems, allocation of resources and capacity. Simulation is a tool which is able to take the complexity and the stochastic nature of healthcare systems into account because in testing different solution proposals it is quite impossible to directly implementing those solution into real environments [16].

Simulation can be used to reduce chances of failure before an existing system is changed or a new system is built. The purpose is to meet system's specification by eliminating unforeseen bottlenecks, preventing under or over utilization of resources and optimizing system performance [17]. Samaha and Armel [18] presented a simulation model of Cooper Health System's Emergency Department with the target to construct a model which able to represents the existing operation and evaluate alternatives to reduce patients LOS. Takakuwa and Shiozaki [19] discovered the patients spent most of their time waiting for treatment for emergency beds, doctors, drips and stretchers. Kozlowski et al. [20] used DES in modeling and improving the flow of patient through emergency department. Kuo et al. [21] used simulation approach to analyze how the allocation decisions impact patient's experience in the emergency department.

DES is recognized as an important research technique to support decision making due to its versatility, flexibility and analysis potential [22]. An application of DES modeling is to determine the impact of critical resources (bed, doctors and nurses) on key performances (queuing time and LOS) has been discussed by [23]. According to Kuljis et al. [24], DES can be represented by a series of events at discrete time intervals which it is a stochastic modeling approach grounded on queuing theory where movement of entities in queuing system is directed by probability distributions.

DES support animations and also graphics visualization which makes the DES is a right approach to easily communicate with healthcare management. The animations provide better understanding of the system and

justification for factual figures. DES tends to dominate health care operations as DES can handle patients' waiting time and resource allocation problem [25]. DES is not only simpler to implement but also less detailed than continuous simulation [17].

Raunak et al. [26] used DES to describe the architecture of ED and used it to suggest efficiency improvements to the hospital management. Results of the research show that the proposed architecture is easy to use and flexible for solving simulation problems. In another research, Jennifer et al. [27] used DES approach to model the ED in order to predict patient load and crowding. Duguay and Chetouane [28] also used DES approach to reduce waiting times of the patient, improving service delivery and throughput time of an ED

Single implementation of DES is not sufficient. There are many research that combined DES with other techniques or approches for resources allocation, scheduling, patient flow, emergency overcrowding and improving efficiency of emergency department operations. Some of the techniques used are linear programming, mixed integer programming, data mining, particle swarm optimisation, system dynamics, and genetic algorithm. Ceglowski et al. [29] combined DES with data mining approach for a value added view of ED operations to better understand the patient's path and treatments.

Lo and Lin [30] used Particle Swarm Optimization (PSO) for physician scheduling in a hospital ED. PSO meta-heuristic optimization method is used to search for the most appropriate shift assignment for staffs working in an emergency room. Hajari and Delavar [31] also used PSO approach in their study in order to solve the ED problem regarding the emergency services. PSO is greatly used for optimization problem in ED especially for resources optimization and staffing. Azcarate et al. [32] used a metaheuristic and simulation approach to analyze management problems in a healthcare context. Fruggiero et al. [33] combined computer simulation and ant colony optimization to optimize patient scheduling while balancing the workload between and within resource types. Baesler and Sepulveda [34] present a multiobjective simulation optimization model for a cancer treatment.

All the above research has shown the effectiveness of the DES and optimization technique towards the simulation model building, allocation of resources, patient flow management and scheduling of staff in ED which can reduce most of the problems occurred.

PROPOSED METHODOLOGY

Based on aforementioned of the current situation in ED, it seems necessary to find more efficient ways to utilize available limited resources in order to minimize patient's LWT and LOS in ED. Hence, this study proposed a modeling approach that is to be used for assessment and strategic planning of ED by the management. The objectives are to examine and allocate the resource requirements (such as staffing and physical capacities) efficiently in order to improve the overall patient experience in ED. This is to ensure that service capacity is equal to patient demand. The model is hoped not only serve to evaluate the current situation at ED facilities and provide potential recommendations, but will also serve as a tool that can helps in examining the "what-if" scenarios.

Simulation Model Development

As mentioned in Section 3, there are few approaches in simulation modeling. Here, we used DES approach to model the ED operations. There are many DES structure or modeling steps to construct simulation model as recommended by previous research [35-36]. The similar steps involved in simulation modeling in this study are as follows:

1. Problem Definition
2. Setting project objectives and plan
3. Model Conceptualization
4. Data Collection and Analysis
5. Model Development
6. Verification and Validation
7. Output Analysis
8. Optimization Approach

At the initial phase (problem definition and setting objectives and project plan), interviews with the ED administration (head of department, specialist, medical officer, medical assistant) have helped to identify the

problems of the ED operations including the flow and processes. Based on the problems and objectives setting, the real world environment is illustrated into conceptual model. The conceptual model represents the pathway of patient flows in receiving the treatment. It is important to identify the flow of patient through ED which includes types of services obtained.

Data collection and analysis process involve determining the data needed to act as an input to the simulation model (what data is needed, what data are available, are existing data valid for the required purposes and how to gather the data). Data process is conducted by interviewing the ED administrators, review of documents and observations. Gathered data are converted into the form of distribution functions for simulation modeling. Once the data collection and analysis process are completed, the conceptual model constructed before is translated into simulation model by using Arena simulation software 14.5.

The completed model is then verified and validated. Verification process is to ensure the simulation model operation follows the flowchart of the conceptual model. This process will be confirmed with the helps from ED administrators. The validation process test if the simulation model represents the real world environment by comparing simulation output with historical data output. Once the model is verified and validated, the simulation model has to be run to acquire the outputs. Expected output from the simulation model results are average patient's LWT, LOS and resource's utilization rates. From the simulation model output, the bottlenecks to the system can be identified. Then, the "what-if" analysis will be performed and evaluated by using optimization method. Figure 1 below shows the simulation modeling steps involved.

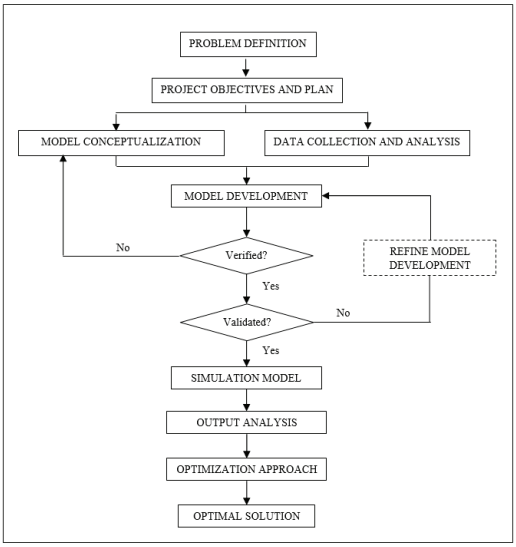

FIGURE 1. Simulation modeling steps

Integration of Simulation and Optimization

Simulation is a valuable technology to examine the "what-if" scenarios to obtain the solution of problems. However, simulation cannot automatically provide an optimal solution [37]. Simulation optimization is the most recently significant new simulation advances and it is used to find the possible optimal solution based on the output from the simulation [38].

Metaheuristic optimization is a popular method that serve as optimization engine when combining simulation and optimization. It is an iterative generation process to guide discovery and exploit in the search space, the learning strategies of subordinate heuristic are used to structure information in order to find efficiently near-optimal solutions [39]. There are four meta-heuristics methods that have primarily been applied with some success to simulation optimization; Simulated Annealing, Genetic Algorithm, Tabu Search and Scatter Search [40].

The idea of this study is to find the optimal configuration of ED resources that can reduce patients' LOS depending on the available resources. The general mathematical formulation for this problem can be expressed as:

$$
\begin{aligned}
&Min\ S = f(X_i, ..., X_n) \\
&s.t.\quad L_i \le X_i \le U_i \ \text{ for } i = 1, ..., n, \\
&\qquad X_i \ \text{ is integer } i = 1, ..., n.
\end{aligned} \tag{1}
$$

Where S represents the total average length of stay of patient which is express as a function of input parameters $(X_i, \ldots, X_n)$. L_i and U_i are the minimum and maximum capacity of resources and n is a total number of constraints. All values are set by the ED management.

Therefore, in order to solve the above function (1), we will follow metaheuristic optimization procedure as stated in [41] and as shown in Figure 2. The simulation model is viewed as a black box function evaluator (tool that generate objective functions and constraints). Based on the output analysis from simulation model, the metaheuristic optimizer will indicates a set of values for the input parameters (for example; number of beds, number of doctors, number of staff nurses and number of ECG machines). Then these input parameters are simulated and the output or responses (average LWT, average total LOS, doctors utilization rates, staff nurses utilization rates, etc.) generated from this simulation is used by optimizer to search for improved solutions and decides the next trial solution to be evaluated. The process continues until the termination conditions of optimization process are met.

Nowadays, many simulation software packages contains an optimization module which is used to perform optimization process by using metaheuristic techniques. Arena simulation software that we used in developing simulation model contains an optimization module named OptQuest, which used scatter search method. Therefore, we will explore this method to find the optimal solution to the problem identified in the simulation model.

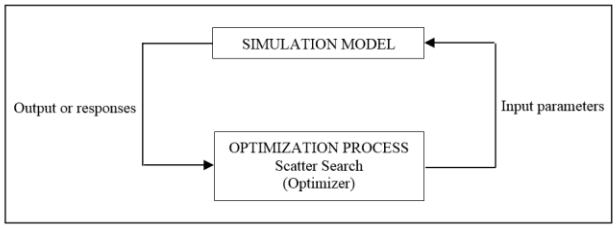

FIGURE 2. Simulation optimization process

CONCLUSION AND FUTURE RESEARCH

This study is currently in the preliminary stage and the proposed framework is still under consideration. Modeling a complex system such as ED is quite complicated because there are many factors (internal and external) affecting the ED operations. Those factors must be studied and included into the framework in order to ensure a more credible and accurate model. The healthcare industry is quite different because it always deals with human and human behaviors are unpredictable. Therefore, future research should also emphasize on human behaviors such as the physical and emotional aspects. Other than that, the optimization methods to be integrated into the simulation model must first be determined and studied in detail. There are many methods under meta-heuristic approach that can be used to find optimal solutions and each of them have their own advantages and disadvantages. Finding the suitable method(s) to solve the problem is important to ensure that the optimal solution able to give impacts not only to the ED management but also to the patients. Analysis from the model is hoped to help the management in understanding their system well and assist them in the decision making process.

ACKNOWLEDGMENTS

The authors would like to thank Universiti Teknologi MARA, Universiti Kebangsaan Malaysia and Kementerian Pendidikan Malaysia for their trust and support of this work. The authors are very grateful to the many individuals involved in this project, their support and comments are highly appreciated.

REFERENCES

1. E. M. W. Kolb, L. Taesik and J. Peck, "Effect of Coupling between emergency department and inpatient unit on the overcrowding in emergency department", Proceedings of the 2007 Winter Simulation Conference, (Washington, DC, 2007), pp. 1586-1593.
2. M. M. Gunal and M. Pidd, "Understanding accident and emergency department performance using simulation", Proceedings of the 2006 Winter Simulation Conference, edited by L. F. Perrone et al. (Monterey, CA, 2006), pp. 446-452.
3. F. F. Baesler, H. E. Jahnsen and M. DaCosta, "The use of simulation and design of experiments for estimating maximum capacity in an emergency room", Proceedings of the 2003 Winter Simulation Conference, (New Orleans, LA, 2003), pp. 1903-1906.
4. N. Ahmad, N. A. Ghani, A. K. Anton and R. Mat Tahar, "A Framework for Emergency Department Capacity Planning Using System Dynamics Approach and The Theory of Constraints Philosophies", Proceedings of the 24th European Conference on Modelling and Simulation, edited by A. Bargiela et al. (ECMS 2010, Kuala Lumpur, 2010), pp. 143-148.
5. N. C. Hong and A. N. Ghani, "A Model for Predicting Average Ambulance Service Travel Times in Penang Island", Proceedings of the 2nd IMT-GT Regional Conference on Mathematics, Statistics and Applications, (Universiti Sains Malaysia, Penang, 2006).
6. Pesakit bertambah punca sesak, SINAR HARIAN. http://www.sinarharian.com.my/mobile/edisi/selangor-kl/pesakit-bertambah-punca-sesak-1.386782 [5 Mei 2015] (in Malay).
7. Health Informatics Centre, *Health Indicators 2012*, Planning and Development Division, Ministry of Health Malaysia, Kuala Lumpur, 2012.
8. Executive Scottish Report, *A guide to service improvement: Measurement, analysis, techniques and solutions*, Edinburgh: St. Andrew's House, 2005.
9. M. J. Cote, Understanding Patient Flow. *Dec. Line* 31: 8-10 (2000).
10. J. R. Van Sambeek, F. A. Cornelissen, P. J. Bakker and J. J. Krabbendam, Models as instruments for optimizing hospital processes: a systematic review. *Int. J. Health Care Quality Assurance*, 23, 356-377 (2010).
11. S. Elbeyli and P. Krishnan, (2000) In-Patient flow analysis using ProModel simulation package. *FREC SP00-02, University of Delaware* available at http://www.udel.edu/FREC/PUBS/SP00-02.pdf.
12. H. R. Feili, Improving the Health Care Systems Performance by Simulation Optimization. *J. of Math. & Comp. Sci.* 7: 73-79 (2013).
13. M. A. Ahmed and T. M. Alkhamis, Simulation optimization for an emergency department healthcare unit in Kuwait. *Euro. J. of Ops. Res.* 198: 936-942 (2008).
14. H. Eskandari, M. Riyahifard and S. Khosravi, "Improving the Emergency Department Performance Using Simulation and MCDM Methods", Proceedings of the 2011 Winter Simulation Conference, edited by S. Jain et al. (Phoenix, AZ, 2011), pp. 1211-1222.
15. J. B. Jun, S. H. Jacobson and J. R. Swisher, Applications of Discrete Event Simulation in Health Care Clinics: A Survey. *J. of the Ops. Res. Soc.* 50: 109-123 (1999).
16. C. D. Barnes, J. L. Quiason, C. Benson and D. McGuiness, "Success Stories in Simulation in Healthcare", Proceedings of the 1997 Winter Simulation Conference, Informs Simulation Society, edited by S. Andradottir et al. (Atlanta, GA, 1997), pp. 1280-1285.
17. A. Maria, "Introduction to Modeling and Simulation", Proceedings of the 1997 Winter Simulation Conference, edited by S. Andradottir et al. (Atlanta, GA, 1997), pp. 7-13.
18. S. Samaha, W. S. Armel and D. W. Starks, "The use of simulation to reduce the lenght of stay in an Emergency Department", Proceedings of the 2003 Winter Simulation Conference, edited by S. Chick et al. (New Orleans, Lousiana, 2003), pp. 1907-1977.
19. S. Takakuwa and H. Shiozaki, "Functional Analysis for Operating Emergency Department of a General Hospital Operations", Proceedings of the 2004 Winter Simulation Conference, edited by R. G. Ingalls et al. (Washington, DC, 2004), pp. 1993-2011.
20. D. Kozlowski, C. B. Mogensen and N. C. Petersen, Discrete Event Simulation Modelling for an Improved Patient Flow at the Emergency Department, Sygehus Lillebaelt, Kolding. *Scand. J. of Traum. Resus. and Emerg. Med. 2012* 20: 14 (2012).

21. Y. H. Kuo, J. M. Y. Leung and C. A. Graham, "Simulation with Data Scarcity: Developing a Simulation Model of a Hospital Emergency Department", Proceedings of the 2012 Winter Simulation Conference, edited by C. Laroque et al. (Berlin, Germany, 2012), pp. 979 – 990.
22. M. Jahangirian, T. Eldabi, A. Naseer, L. K. Stergioulas and T. Young, Simulation in Manufacturing and Business: A Review. *Euro. J. of Ops. Res.* 1: 1-13 (2010).
23. A. Komashie and A. Mousavi, "Modeling emergency departements using discrete event simulation techniques", Proceedings of the 2005 Winter Simulation Conference, edited by M. E. Kuhl et al. (Orlando, FL, 2005), pp. 2681-2685.
24. J. Kuljis, R. J. Paul and L. K. Stergioulas, "Can health care benefit from modeling and simulation methods in the same way as business and manufacturing has?", Proceedings of the 2007 Winter Simulation Conference, eidted by S. G. Henderson et al. (Washington, DC, 2007), pp. 1449-1453.
25. S. Roberts, "Tutorial on the Simulation of Healthcare Systems", Proceedings of the 2011 Winter Simulation Conference, (Phoenix, AZ, 2011), pp. 1408-1419.
26. M. Raunak, L. A. W. Osterweil, L. Clarke and P. Henneman, "Simulating Patient Flow through an Emergency Department using process-driven discrete event simulation", Proceedings of the 2009 ICSE Workshop on Software Engineering in Health Care, (Washington, DC, 2009), pp. 73-83.
27. L. Jeniffer, T. Richard and T. Olsen, Review of Modeling Approches for Emergency Department Patient Flow and Crowding Research. *J. of Acad. Emerg. Med.* 11: 1371-1379 (2011).
28. C. Duguay and F. Chetouane, Modeling and Improving Emergency Department Systems using Discrete Event Simulation. *J. of Simula.* 4: 311-320 (2007).
29. R. Ceglowski, L. Churoilov and J. Wasserthiel, Combining Data Mining and Discrete Event Simulation for a value added view of a hospital emergency department. *J. of the Ops. Res. Soc.* 58: 246-254 (2007).
30. C. C. Lo and T. Lin, "A Particle Swarm Optimization approach for physician scheduling in a hospital emergency department", Natural Computation (ICNC), 2011 Seventh International Conference, (Shanghai, China, 2011), pp. 1929-1933.
31. H. Hajari, M. R. Delavar, Particle Swarm Optimization in Emergency Services. *Int. Arch. of the Photogrammetry, Rmt. Sensing, and Spatial Info. Sci.* 8 (In Press): 1-4 (2010).
32. C. Azcarate, F. Mallor, and A. Gafero, Multiobjective Optimization in Health Care Management: A Metaheuristic and Simulation Approach. *Algo. Ops. Res.* (2): 186-202 (2008).
33. F. Fruggiero, A. Lambiase and D. Fallon, Computer Simulation and Swarm Intelligence Organisation into an Emergency Department: A Balancing Approach across Ant Colony Optimisation. *Int. J. of Sci. Ops and Info.* 3: 142-161 (2008).
34. F. F. Baesler and J. A. Sepulveda, "Multi-Objective Simulation Optimization For A Cancer Treatment Center", Proceedings of the 2001 Winter Simulation Conference, edited by B. A. Peters et al. (Arlington, VA, 2001), pp. 1903-1906.
35. R. E. Shannon, "Introduction to the Art and Science of Simulation", Proceedings of the 1998 Winter Simulation Conference, edited by D. J. Medeiros et al. (Washington, DC, 1998), pp. 7-14.
36. J. S. Carson II, "Introduction to Modeling and Simulation", Proceedings of the 2005 Winter Simulation Conference, edited by M. E. Kuhl et al. (Orlando, FL, 2005), pp. 16-23.
37. A. M. Law and M. G. McComas, "Simulation based Optimization", Proceedings of the 2002 Winter Simulation Conference, edited by E. Yücesan et al. (San Diego, CA, 2002), pp. 41-44.
38. M. C. Fu, "Simulation Optimization", Proceedings of the 2001 Winter Simulation Conference, edited by B. A. Peters et al. (Arlington, VA, 2001), pp. 53-61.
39. M. Gendreau, *Handbook of Metaheuristics*, Springer New York, 2010.
40. I. H. Osman, and G. Laporte, Metaheuristics: A bibliography. *Annals of Ops. Res.* 5: 511-623 (1996).
41. J. April, F. Glover, J. P. Kelly and M. Laguna, "Practical Introduction to Simulation Optimization", Proceedings of the 2003 Winter Simulation Conference, edited by S. Chick et al. (New Orleans, Lousiana, 2003), pp. 71-78.